MORROW COUNTY CHLORIDE CONTAMINATION 1974

A re-evaluation of surface and ground water chloride concentrations since 1966

by Harold W. Heiss, Jr.
in fulfillment of Senior
Thesis Requirement
August, 1974

Faculty Advisor: Wayne A. Pettyjohn, Ph.D.
Dept. Geology & Mineralogy

TABLE OF CONTENTS

Introduction

Since the discovery of oil in Morrow County, Ohio in 1961 the area's ground and surface water has become grossly contaminated by oil-field brines. This paper is a study of the effects of this contamination after 13 years as reflected by chemical analyses of surface and ground water.

The data for this study were collected during July and August, 1974. It should be noted that during these months, the area was experiencing relative drought conditions having a total rainfall of only 2.22 inches.

The study area includes the northeast lobe of the Scioto River drainage basin and specifically the basins of Shaw and Whetstone Creeks and their tributaries in central Ohio. Since 1961 and particularly since 1964, these streams have been adversely affected by both direct and indirect introduction of oil-field brines into them. The water-well data were collected from private residences adjacent to the streams.

The purpose of this study was to evaluate the overall spread of chloride contamination since 1961, present a picture of conditions as they existed during the summer of 1974, and compare the differences.

Two studies dealing with contamination by oil-field brines in Shaw and Whetstone Creeks were conducted by Shaw (1966) and Boster(1967). The data from their studies are used for comparison and contrast throughout this paper.

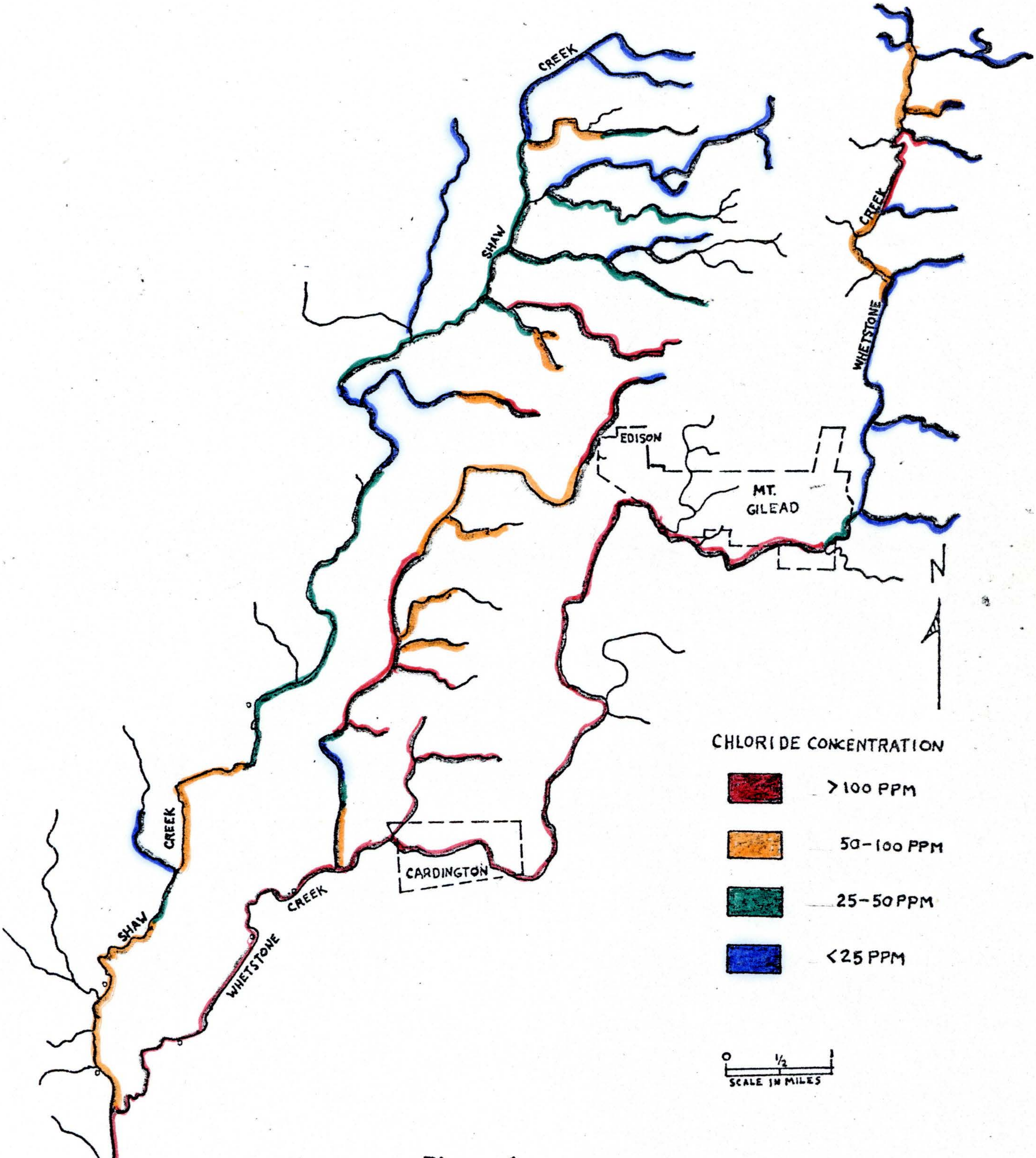


Figure 1

CHLORIDE CONCENTRATION
COLOR INDEX MAP -- Jul-Aug 74

Figure 2

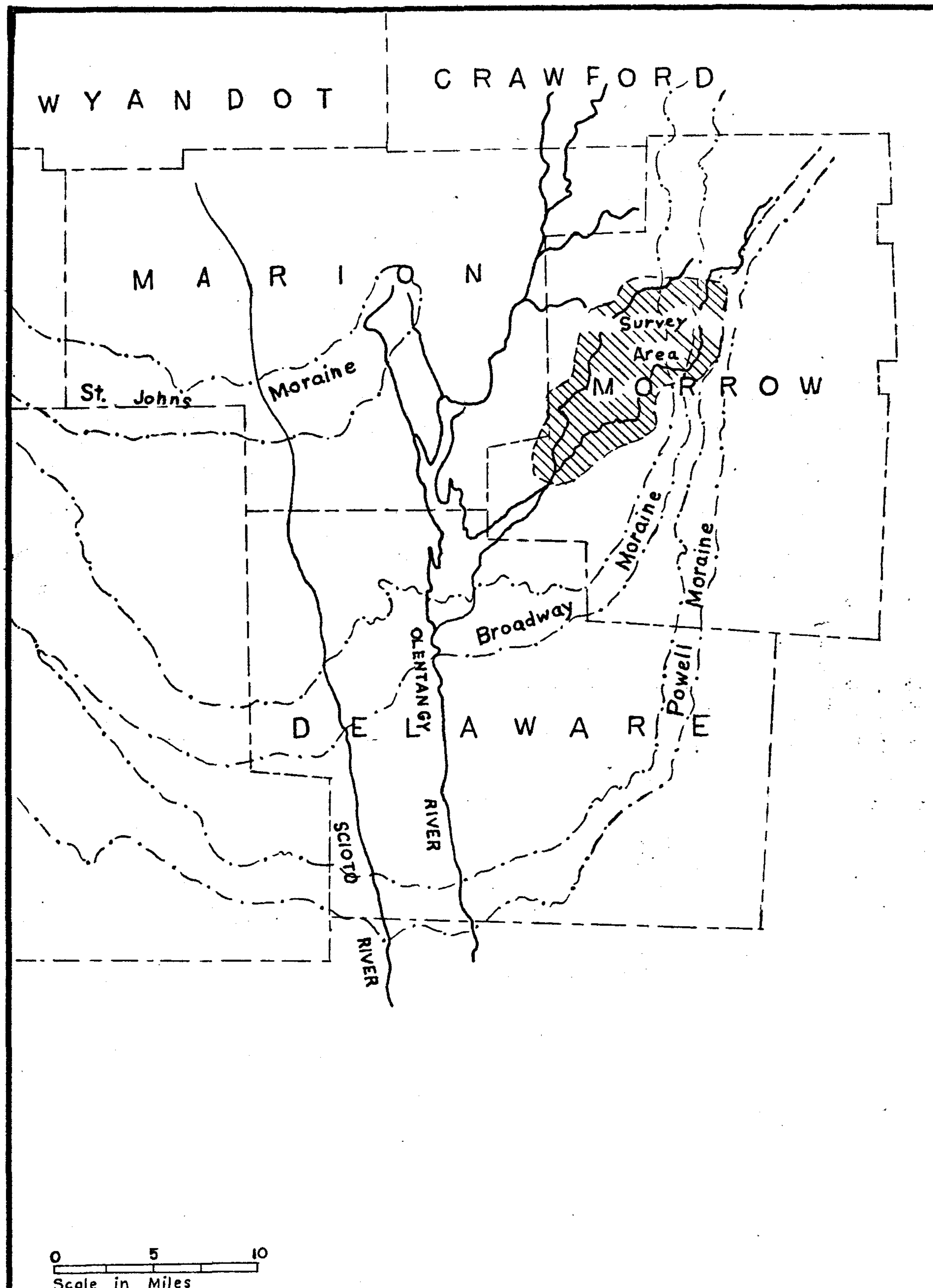
Location of Enclaves of Concentration
greater than 25 mg/l in 1965

General Features of the Area

Farming is the main industry of the study area with the main crops being corn, soybeans and winter wheat. The production of oil is the second most active industry and coexists with farming in the same fields. Shaw and Whetstone basins have relatively low population densities and are sparse in new housing and recreational developments compared to adjacent areas to the north and east. Perhaps this is due in part to the unpleasant odor of the natural gas, which permeates the air near most of the oil wells.

The major villages of the area are located along Whetstone Creek, and include in downstream order, Mt. Gilead, Edison, and Cardington. Each of these villages draw their water from separate municipal well fields and have water-treatment facilities. Also each possesses a sewage treatment plant, the effluent of which discharges into Whetstone Creek. Water supplies for the smaller hamlets and rural dwellers are drawn from wells, cisterns, or impoundments. Sewage treatment is mainly by septic tank and, in some cases, chemical toilets are utilized.

Whetstone Creek is the main tributary of the Olentangy River and it has a drainage area of 114 square miles. Shaw Creek, which joins Whetstone Creek about 4 miles northwest of Cardington, drains 30 square miles and forms the western boundary of the study area. Both of these streams lie on a glacial till plain with relatively steep slopes along Whetstone Creek and nearly flat land along Shaw Creek. In the headwaters north of Mt. Gilead Whetstone Creek lies between the Broadway and the Powell moraines. The pre-glacial topography onto which these moraines were deposited on stood higher to the east side of the study area, hence dictating the greater relief along Whetstone Creek. Topographic



Index map for Regional Survey Area

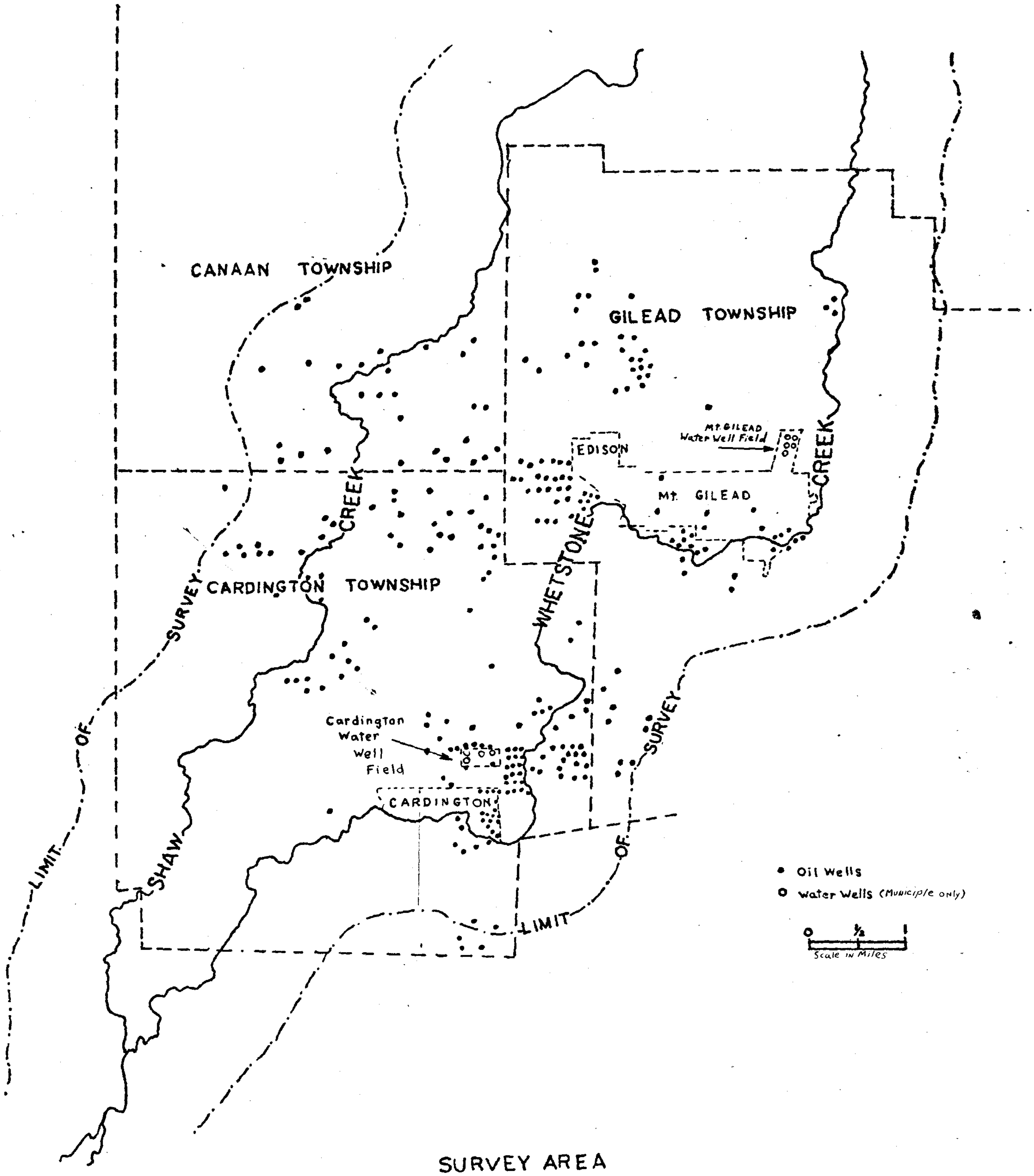
SHAW (1966)

elevations range from 1215 feet in the northeast sector of the study area to 950 feet in the southwest.

The glacial till that covers Morrow County is composed of unconsolidated clay, sand, and gravel. The till is underlain by the Ohio Shale, a black, impermeable Devonian unit that comprises the bedrock in most of the area. The top of the underlying Delaware Limestone is exposed in the Whetstone Creek stream bed immediately adjacent and southeast of Mt. Gilead. Here the Ohio Shale forms cliffs approximately 50-60 feet high on the northeast side of the creek. Generally, the Ohio Shale is only exposed in thin outcrops along the major streams and in their beds throughout the study area.

Oil Production in Morrow County

Oil drilling has been a major activity in Morrow County since 1961 when a flowing well was completed. More than 2000 wells were drilled in the following three years, with approximately 600 becoming producing wells. The oil is situated in small trap pools between a Cambrian age dolomite erosional topography and Ordovician shale, which rests unconformally above. The wells range in depth from approximately 2900-3500 feet. During the past five years drilling has been sharply reduced. Only seven permits were issued for 1974. This is attributed to several reasons. The oil companies report that the existing wells are pumping the maximum amount of oil economically feasible for the operating and drilling expense per pool. The well drillers and operators, however, believe that more new wells should be drilled, and could be if it were not for state laws and in some cases land owners who restrict the drilling. The state laws of which the operators speak are those enacted by the Ohio



SURVEY AREA
MORROW COUNTY, OHIO

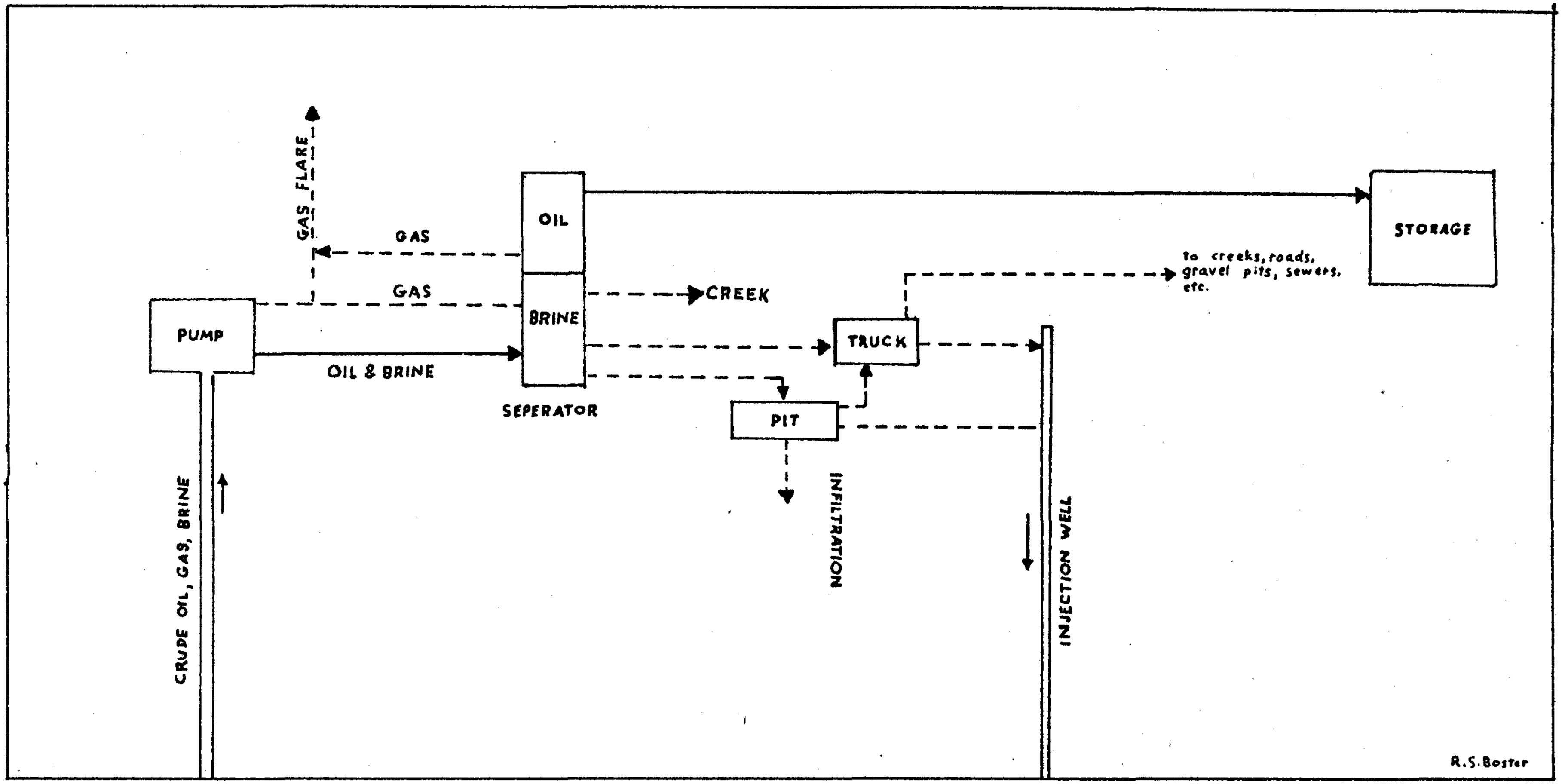
Division of Oil and Gas concerning disposal of oil-field brines. Oil-field brine is the by-product of oil production. This highly mineralized water has chloride concentrations that range between 35,000 and 60,000 mg/l.

Some farmers in the area are opposed to oil exploration and drilling on their property. In fact, two such farmers evicted the writer from their land during an attempt to collect surface-water data. Each gave the reason of having only bad experiences with "oil people" (contamination of private water wells with brines, fears for their cattle drinking contaminated water from streams and springs and unauthorized people tramping through their fields). More than 30 million barrels of crude oil have been extracted from the Morrow County oil pools since their inception in 1961 and considerably more brine has been pumped and disposed of during that same time.

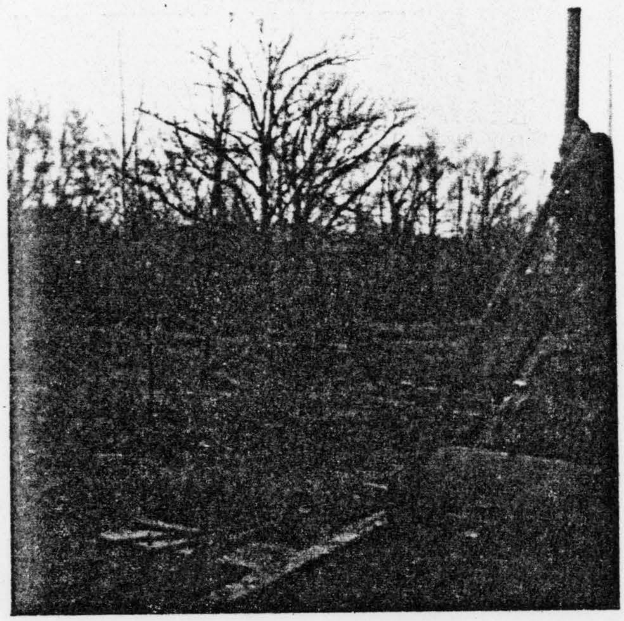
Oil-Field Brine Disposal Methods

The disposal of oil-field brines is the chief problem facing Morrow County land owners and oil-well operators. The early methods (1961-1964) of brine disposal were simple. The brine was channeled to the nearest stream or, where that was not feasible, collected and disposed of in "evaporation" pits.

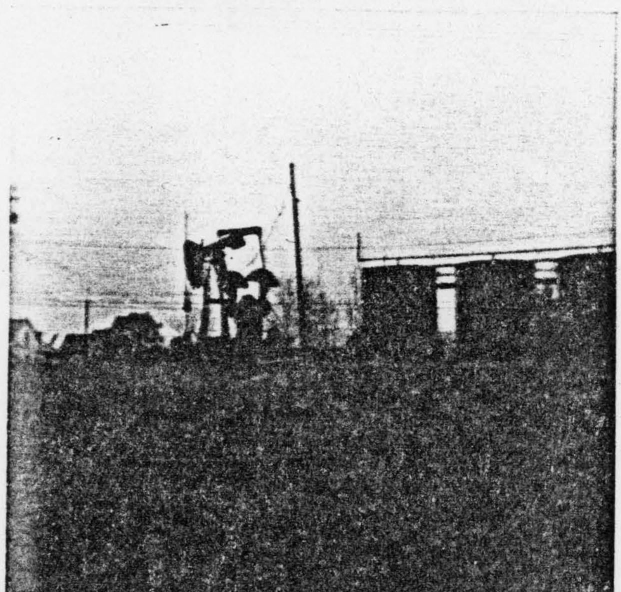
The "evaporation" pits are shallow excavations, usually 10-30 feet square, into which the brine is placed. The original idea was that the fluid would evaporate, leaving the dissolved salts on the surface. This was a common method utilized in the Texas oil fields with marginal results. The mean evaporation rate in Texas, however, ranges between 48 and 80 inches per year, while that of Ohio hovers between 29 and 35 inches per year. The thick black oil residue, which covers the fluid



STORAGE
GAS FLARE
GAS
OIL
GAS
BRINE
CREEK
to creeks, roads, gravel pits, sewers, etc.
PUMP
TRUCK
OIL & BRINE
SEPERATOR
PIT
INFILTRATION
INJECTION WELL
CRUDE OIL, GAS, BRINE
R.S.Boster



Photograph 1



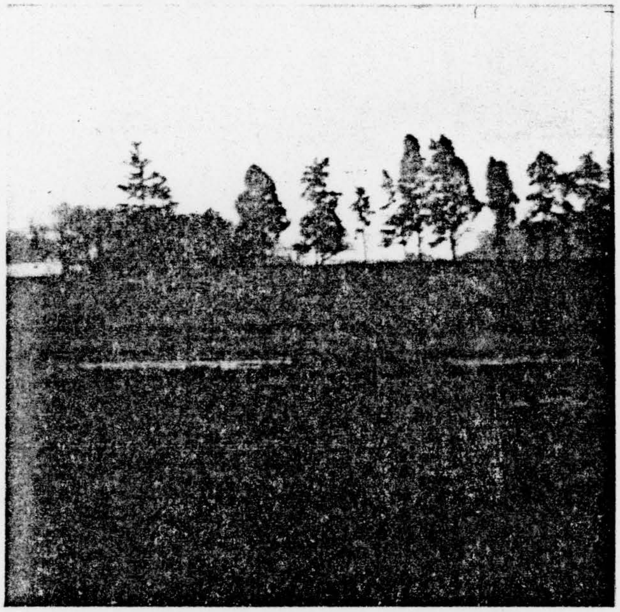
Photograph 2

surface in many ponds, also acts as an evaporation retardant. In many cases the brine infiltrates into the soil and contaminates the underlying ground water. When "evaporation" pits are abandoned, a cosmetic, bull-dozed mound of earth covers the spot to preserve the "natural setting". This practice, however, only prolongs the contamination period by trapping brine crystalsand residues to be dissolved from the soil by infiltrating rain water.

Only when municipal, private and stock water wells became too "salty" to drink, and large trees and fields began to wither did the dire consequences of these disposal methods become evident. Legislation curtailing these methods of disposal was weak and slow in coming. However, in May of 1965 the Ohio State Legislature enacted a law requiring "evaporation" pits to be lined with impermeable materials. A 1-2 foot layer of clay lining a pit is a fairly effective seal, but in many cases a thin layer of vinyl-plastic was used to "line" the pit. The plastic liners are, needless to say, ineffective after several seasons due to wear and lack of maintenance. Many operators didn't install even this "hedge" against the law and, since enforcement is "slow", some unlined "evaporation" pits still exist. (See photographs 3 and 4) This law did, however, increase the use of the contract trucker, who for $10.50 per 40-barrel load, relieved the oil producer of the responsibility for brine disposal.

The contract trucker fills his tank from the surface pits or directly from the oil separator reservoir tank and disposes of it in a variety of ways. Some loads are hauled to high pressure injection wells, which pump the brine back into the oil producing zone and acts as a secondary recharge agent to increase oil production. Other loads are dumped into surface streams, gravel pits, roadside ditches or even spread

Photograph 3



Photograph 4

over gravel road surfaces to "keep down the dust". The latter procedure is sometimes with the permission of township officials.

All brines which are dumped on the surface contaminate ground water to some extent. If all of a 40-barrel load of brine fluid, containing 40,000 mg/l chloride, were to reach the ground water and become well mixed, it would contaminate 2.35×10^6 gallons of fresh water to the extent of 100 mg/l (eight-ten times normal for Morrow County ground water).

The high pressure injection well is very effective in the disposal of brine. The economic aspect of the high pressure disposal well is the chief drawback to its widespread use since the cost of drilling the disposal well is the same as the oil well. Because of this fact very few injection wells are drilled. The most common disposal well is a "dry hole" (an unsuccessful oil well) modified for brine disposal. Each disposal well serves many oil producing wells in its immediate area, but there is an insufficient number to provide all producing oil wells in the Morrow County area with brine-disposal service.

Hydrology and Water Quality

High concentrations of chloride in surface waters in Morrow County are of major interest in this study since much of the time, a chemical quality reflects the general ground-water quality of the area through which the stream flows. In fact surface water samples were collected for this study during a drought and consequently the entire stream discharge consisted of ground-water runoff.

During an extended period of little or no precipitation, streams draw all or nearly all their water from the ground water that discharge into them. When the ground water is grossly contaminated as it locally is in Morrow County, the chemical quality of surface waters is also highly contaminated.

To begin a surface water study a determination of the background concentration of chemical substances in the water must be ascertained. The background concentrations should represent the chemical quality of the water before any outside influence acted upon it (Pettyjohn, 1973). In this case the chloride concentration of the surface streams before oil production was begun would prove to be the natural background of chloride concentration; unfortunately such data do not exist. The background chloride concentration was determined in the northern reaches of the streams near their origins in northeast Morrow County where no oli wells exist. The chloride concentrations of both Shaw and Whetstone Creeks in their headwaters ranged between 3 and 6 mg/l.

The next step of a contamination study is to establish arbitrary limits of concentration to reflect various levels of contamination.

While the Public Health Service's recommended limit for chloride in drinking water is 250 mg/l (milligrams/liter), a surface water concentration of 25-40 mg/l is considered above normal in this study. A concentration of greater than 50 mg/l is considered genuinely contaminated, while concentration greater than 100 mg/l are grossly contaminated. Figure 1 shows the chloride concentration in Shaw and Whetstone Creeks during July and August, 1974.

The Enclave Concept

Keeping in mind the correlation between ground water and stream flow during droughts, the areal extent of chloride contamination in Morrow County can be readily recognized. The high concentrations of chloride seem to be located in pockets. Shaw (1966) recognized these pockets of contamination and applied the term "enclave" to them. He defined an enclave as a volume of contaminated water. The enclave is a three dimensional body of water whose quality has been altered by the influx of oil-field brines. The enclave concept is convenient in describing the formation, movement and dissipation of the chloride contaminated mass.

Shaw delineated many enclaves throughout the Morrow County area (Fig. 2). Because the background chloride concentration is less than 10 mg/l, Shaw used 25 mg/l as the lowest and hence the most encompassing contour line to delineate the limits of the enclave. The map (Fig. 2) shows the areal extent of contaminaton along Shaw and Whetstone as it existed in 1965. Cross-sectional traces have also been drawn for 1974 traverses.

Enclave Movement

During this study traverse were conducted across known enclave sites in order to ascertain movement of the enclave. The areal extent of the

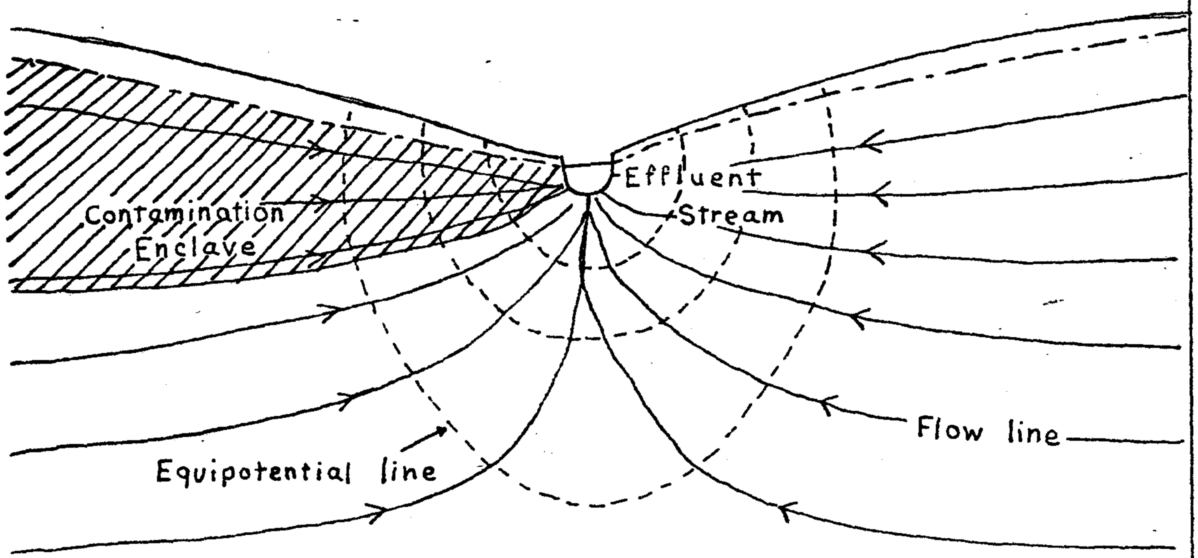


Diagram showing normal ground-water flow near an effluent stream. Cross-hatched area represents a contamination enclave contained in ground-water flow.

enclave was estimated and drafted on a 7½ minute topographic map. Wells and springs inside the enclave area were located in as nearly as a straight line as was possible in order to draw a cross-sectional representation of the enclave and determine its movement over the past nine years.

Two enclaves were chosen for this purpose. The first a relatively small mass located south of Cardington, Ohio, is bisected by a county road. Private farm wells and a 1¼ mile long stretch of road provide a good downslope cross-section that is nearly perpendicular to Whetstone Creek (Cross-section A-A', Fig. 3). The second site was chosen for the contrast of conditions along the cross-sectional trace. The second trace runs NW-SE and crosses fron an area of backgroung chloride of 3 mg/l, through a small isolated enclave, into a large enclave adjacent to parts of both Shaw Creek and Big Run -- Whetstone Creek's major tributary (Cross-section B-B', Fig. 4).

The northwest Cardington cross-section reflects a condition where ground water, with a concentration of less than 40 mg/l, occurs in a 15 feet thick zone that overlies more highly mineralized water. The streams are receiving part of their flow from the deeper, more contaminated ground water and hence suffer a higher degree of contamination than do the adjacent wells. The chloride concentrations increase steadily towards the southeast end of the cross-section. The increase is due to the encroachment of an enclave on the southeast side of Big Run.

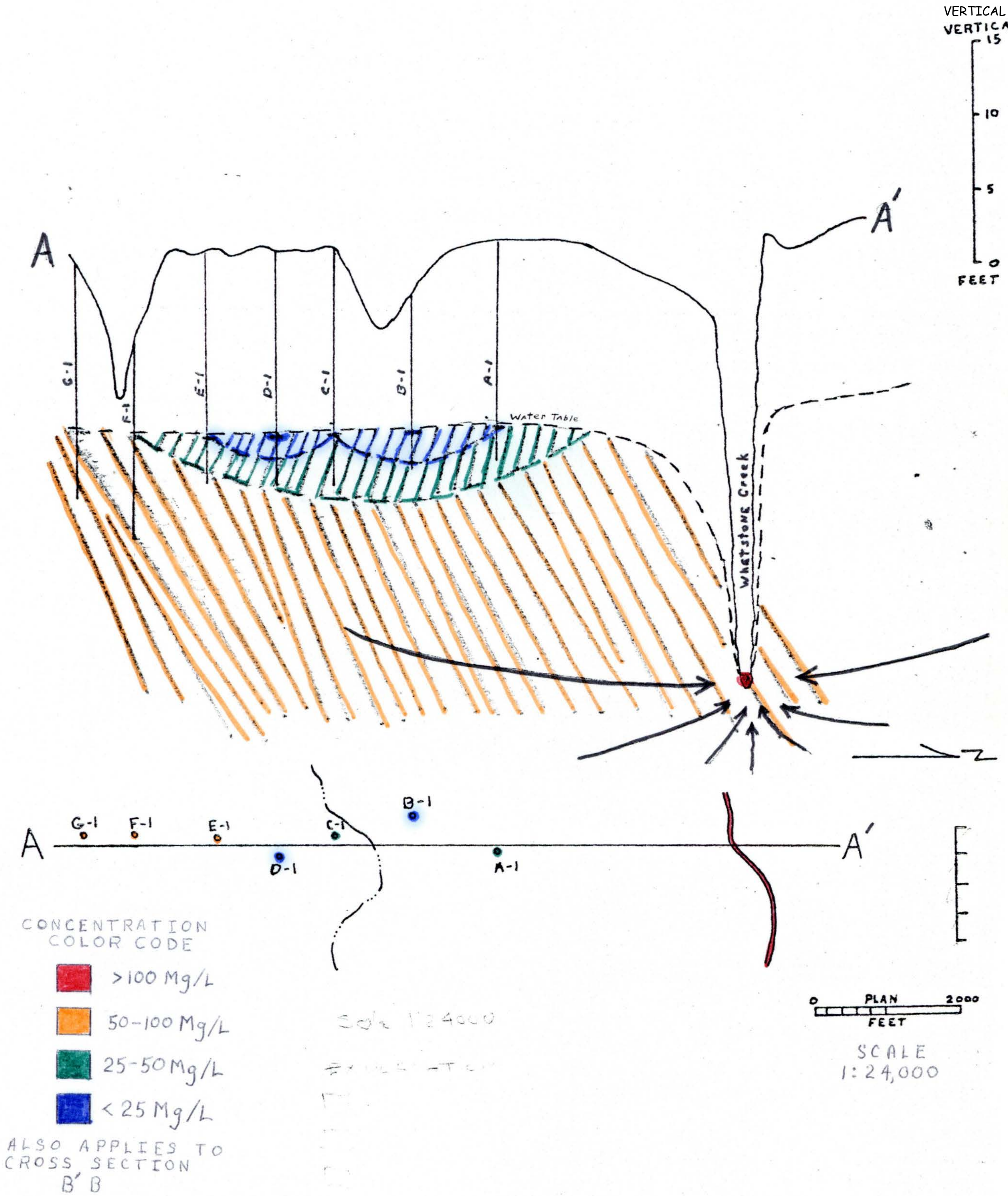
Big Run suffers contamination from a high density of oil wells (many now deserted with bulldozed-over "evaporation" pits) just north of the cross-sectional point.

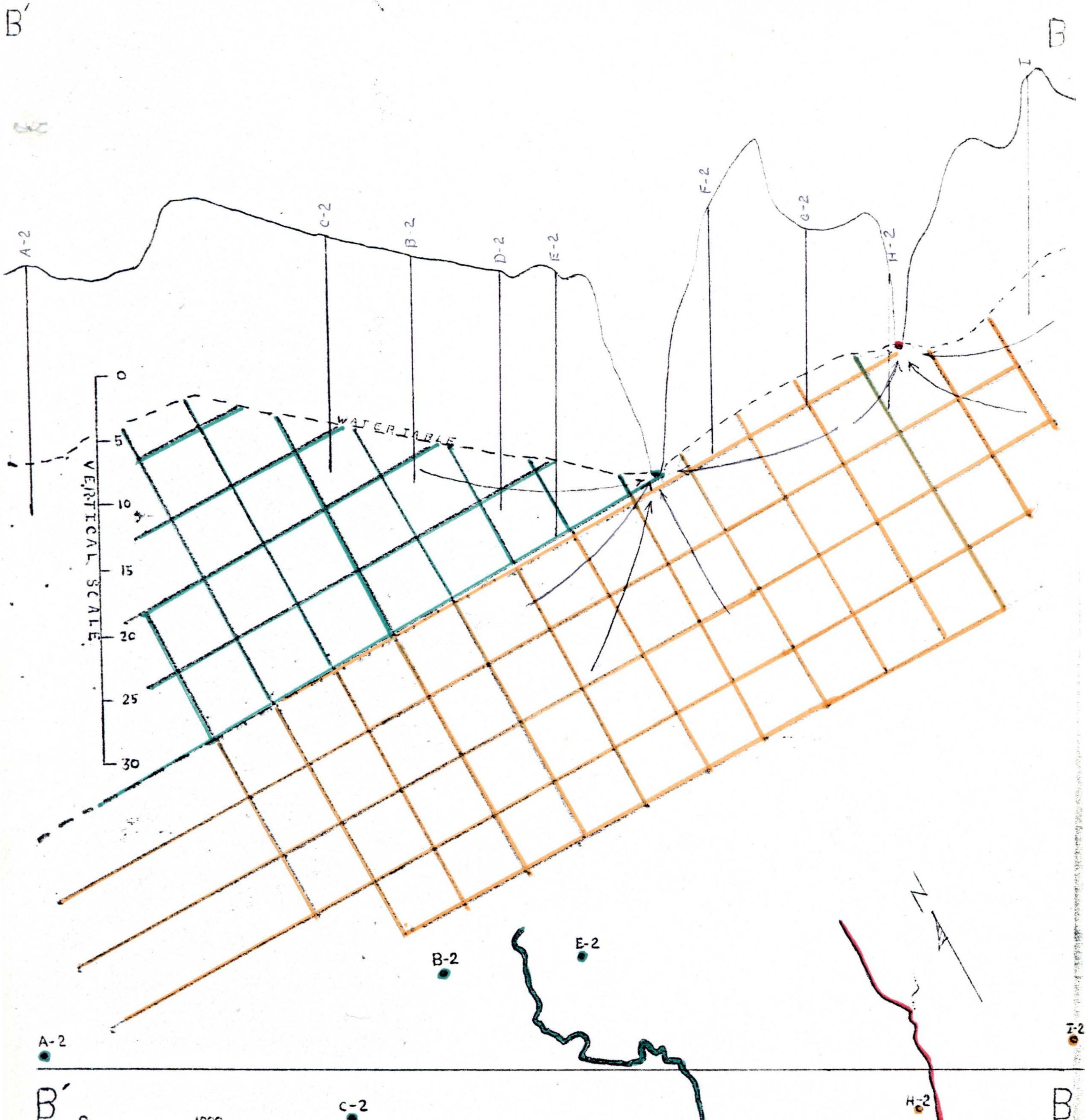
It should be noted that the normally greater rate of water movement at the upper boundary of the water table is now considerably slowed, due to little or no precipitation which in turn reduces the water level gradient.

The higher density contaminated water, which was usually swept along the high velocity upper boundary until discharged into a stream, now moves very slowly and is allowed to mix with lower level ground water. Hence the high chloride water usually found near the surface should not be as contaminated during a prolonged dry period as that water would be during the wet spring months.

The enclave south of Cardington is less complicated. The concentrations increase to the south. The increase to the south is possiby due to the migration of chloride contamination from the high ground to the northeast (which hosts a high concentration of oil wells less than a mile away), which may be induced by the West Branch of Alum Creek to the south.

Both enclaves however seem to remain the same as when observed in 1965. Some enclave movement may have occurred uniformly in an outward direction, however the movement of major concentration levels appear to remain generally the same as when measured in 1965, 1966, 1967. The 25 ng/l concentration is a very low level of contamination when dealing with an area which has been so highly contaminated. A 75-100 mg/l concentration might be more useful when attempting the detection of enclave movement. The 25 mg/l concentrations will linger in the area for many years while the higher concentrations will move or disappear more rapidly during the natural ground water flushing process.


VERTICAL
VERTICAL
15
10
5
0
FEET
A
A′
G-1
F-1
E-1
D-1
C-1
B-1
A-1
Water Table
Whetstone Creek
N
G-1
F-1
E-1
D-1
C-1
B-1
A-1
A
A′
CONCENTRATION
COLOR CODE
>100 Mg/L
50-100 Mg/L
25-50 Mg/L
< 25 Mg/L
ALSO APPLIES TO
CROSS SECTION
B′ B
0
PLAN
2000
FEET
SCALE
1:24,000


B′
B
A-2
C-2
B-2
D-2
E-2
F-2
G-2
H-2
I
WATER TABLE
0
5
10
15
20
25
30
VERTICAL SCALE
B-2
E-2
A-2
I-2
B′
B
C-2
H-2
G-2
D-2
F-2
0
1000
SCALE
1:24,000

Chloride Stratification with Depth

Apparent in both cross sections A-A′, B-B′ is the stratification of chloride contaminated ground water. The stratification phenomenon is a function of several variables: the water-table slope, depth to bedrock, the physical properties of the aquifer and the chloride content of the ground water.

Cross section A-A′ exhibits a stratified series of ground water lenses. The even levels of concentration may be the result of the small amount of precipitation, reducing the water-table gradient and thereby slowing ground water flow.

Cross section B-B′ shows a slightly different picture of stratification- a dipping trend to the west. The same relation of less contaminated ground water overlying more contaminated still exists, but as the steep water-table gradient brings in higher concentration from the southeast, the less contaminated ground water is displaced upward and to the west. The displacement should continue westward in the years to come causing further contamination of wells A-2, B-2, C-2, D-2 and E-2. The displacement of less contaminated ground water by more contaminated will continue until the upland areas to the east become diluted by "natural flushing" or the water-table gradient is decreased or reversed.

Conclusion

Ground-water contamination by oil-field brines in Morrow County is widespread. Several areas are still contaminated, which renders the water unfit to drink. Many people in the area however drink water with chloride concentrations greater than the U.S. Public Health limit for chloride (250 mg/l).

Duting the time period of this study, spreading of chloride enclaves may have been accelerated by the prolonged dry weather due to accelerated mixing with fresh water.

The greatest single factor of contamination is the indiscriminate dumping of oil field brine by contract truckers and the use of "evaporation" pits.

The movement of enclaves is very slow. Using the 25 mg/l parameter it is very difficult to determine any movement of the enclave from 1965 to the present (1974). Some data reflect the relatively more rapid enclave movement in areas directly adjacent to streams. Areas with buried "evaporation" pits however seem to remain at the same degree of contamination. However, comparison of the Chloride Concentration Color Index Map (Fig. 1) and the 1965 enclave map reflects definite and beneficial changes. Most notable is the upper reaches of Shaw Creek. The area north of cross-section B-B′ shows considerable improvement. During 1965-1967 the chloride concentration ranged between 58 and 210 mg/l (Shaw, 1966), while the highest concentration found during this study was 32 mg/l. The small enclaves northeast of Mt. Gilead have disappeared completely as well as many others. These areas are small as compared to the whole of the contaminated region but none the less they are evidence of improvement.

The ground-water quality in Morrow County has been drastically altered. The major contamination occurred in the early 1960's; since then many private water wells have recovered somewhat, so as to become potable again after an initial period of heavy contamination. The major problem today is the control of brine disposal techniques by oil-well operators an contract truckers. The use of "evaporation" pits must be entirely abandoned as well as all forms of dumping brine on the surface. The high pressure injection disposal wells should be used as the only brine disposal method.

Chemical Method for Chloride Ion Concentration Determination

Chloride-ion concentrations were measured by using the Mohr titration method. The standard sample employed by this method is 100 ml, which is titrated against a 0.0141N solution of silver nitrate, using potassium chromate as an indicator (APHA Standard Methods, 1960).

The end-point determination for titration is a subjective interpretation of color intensity. However, so as to insure consistency, a standard color blank was used for comparison. The color blank was prepared by titrating a sample only until the indicative orange-pink color began to appear. All samples were collected and titrared by the author so as to insure consistency. Any possible errors in the determined chloride content should not exceed 15 mg/l (by the Mohr method).

Sample Number	pH	Conductivity	Chloride Ion (ppm)	Temperature Centigrade	Collection Date Symbol
W1	8.2	550	77	22°C	B
W2	7.8	1600	142	17°C	B
W3	7.2	825	11	20°C	B
W4	8.0	775	16	23°C	B
W5	8.2	750	34	24°C	B
W6	8.3	900	140	19°C	A
W7	6.0	650	18	20°C	A
W8	6.0	2400	451	18°C	A
W9	7.8	1800	361	20°C	A
W10	6.8	1200	146	19°C	A
W11	7.4	1600	280	19°C	A
W12	5.5	1900	248	19°C	A
W13	7.6	1500	287	20°C	A
W14	3.7	1700	201	20°C	A
W15	3.5	750	29	19°C	A
W16	8.5	1950	275	19°C	A
W17	8.2	2000	311	19°C	A
W18	8.4	1700	335	18°C	A
W19	8.2	2100	312	19°C	A
W20	8.5	1900	219	19°C	A
W21	7.5	1650	268	19°C	A
W22	7.5	1600	261	19°C	A
W23	8.4	1750	264	18°C	A
T1G.S	8.5	510	232	18°C	A

Sample Number	pH	Conductivity	Chloride Ion (ppm)	Temperature Centigrade	Collection Date Symbol
WT1	8.0	900	59	22°C	D
WT2	8.8	600	68	23°C	D
WT3		875	22	21°C	D
WT4		1400	306	23°C	D
WT5		1100	229	21°C	D
WT6		540	54	26°C	D
WT7	9.2	2450	345	21°C	D
WT8	8.3	950	6	21°C	B
WT9	7.8	700	23	21°C	B
WT10	7.2	700	5	24°C	B
WT11	7.4	850	11.0	15°C	B
WT12	6.8	750	5	17°C	B
WT13	7.4	800	3	22°C	B
WT14	7.4	710	12	22°C	B
WS1	8.8	1175	135	24°C	B
WS2	8.2	1400	137	26°C	B
WS3	7.0	4000	591	24°C	B

Sample Number	pH	Conductivity	Chloride Ion (ppm)	Temperature Centigrade	Collection Date Symbol
ST1		1200	17	19°C	E
ST2		650	8	19°C	E
ST3		725	17	23°C	E
ST4		770	27	20°C	E
ST5		520	29	22°C	E
ST6		5000	234	30°C	D
ST7		1000	36	19°C	D
ST8		860	32	24°C	D
ST9		600	8	24°C	C
ST10		900	16	18°C	C
ST11	7.8	950	23	26°C	C
ST12	8.0	1000	26	19°C	C
ST13	8.3	2700	458	21°C	C
ST14	7.6	800	62	22°C	C
ST15	6.2	900	21	22°C	C
ST16	7.0	875	20	21°C	C

Sample Number	pH	Conductivity	Chloride Ion (ppm)	Temperature Centigrade	Collection Date Symbol
S1		850	26	20°C	E
S2	8.2	1000	26	21°C	C
S3	7.8	900	29	26°C	C
S4	6.8	850	6	27°C	C
S5		650	40	23°C	D
S6	6.9	870	38	25°C	C
S7	6.7	800	40	25°C	C
S8	6.5	840	42	23°C	C
S9	6.4	900	59	23°C	C
S10	6.0	750	62	25°C	C
S11	6.5	950	63	23°C	C
S12	6.5	1000	12	23°C	C
S13	6.5	900	77	24°C	C
S14	8.2	950	63	19°C	A

South Cardington Enclave

Sample	Chloride Concentration (ppm)
A-1	26
B-1	25
C-1	29
D-1	25
E-1	42
F-1	57
G-1	55

Northwest Cardington Enclave

Sample	Chloride Concentration (ppm)
A-2	41
B-2	48
C-2	41
D-2	49
E-2	55
F-2	78
G-2	52
H-2	81
I-2	89

Collection Date	Color Code	Letter Symbol
July 13, 1974		A
July 19, 1974		B
July 26, 1974		C
August 10, 1974		D
August 23, 1974		E